Akatsuki's IR2 Nightside Photometry Restoration by Deconvolution

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Motivation: To restore contaminated IR2 images in order to achieve highest photometric accuracy for morphological and analytical studies.

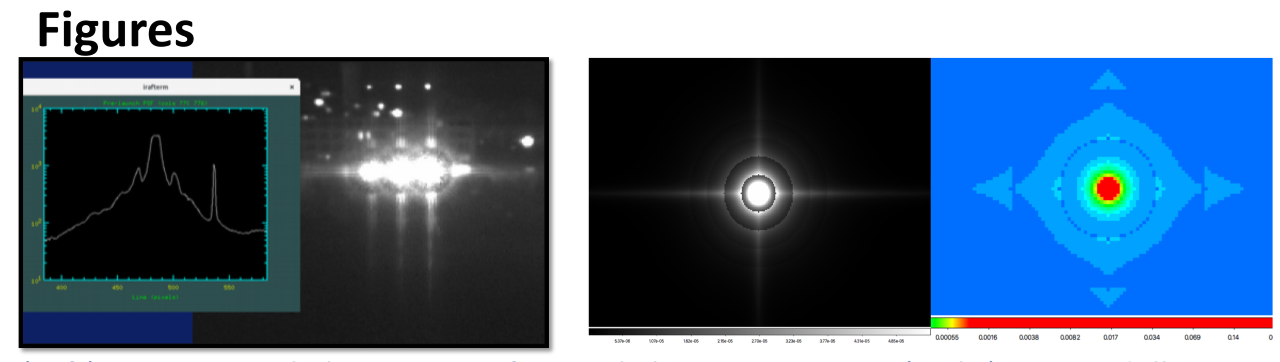
Problems:

- IR2 Point Spread Function (PSF) creating multiple halation rings spread around point source. (Satoh et al. 2017)
- Pixel saturation due to intense sunlight
- Dayside spreading into nightside due to convolution by PSF

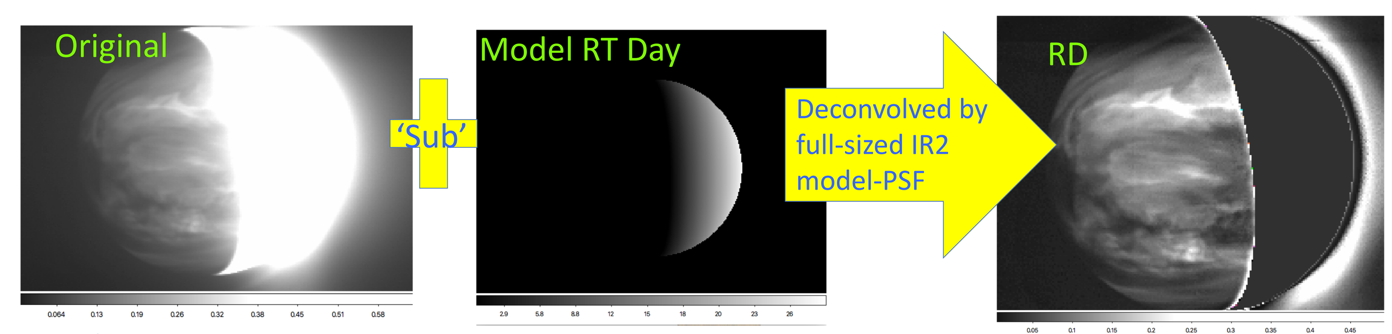
Problem Solving:

- PSF modelling using Moffat Function
- Dayside modelling using Radiative Transfer (RT) calculation (Saturated Dayside)
- Nightside photometry modelling using filter conversion technique (Saturated Nightside)
- Deconvolution by model-PSF using Lucy-Richardson algorithm

Figures



(Left) Experimental observation of street light point sources. (Right) PSF Modelling



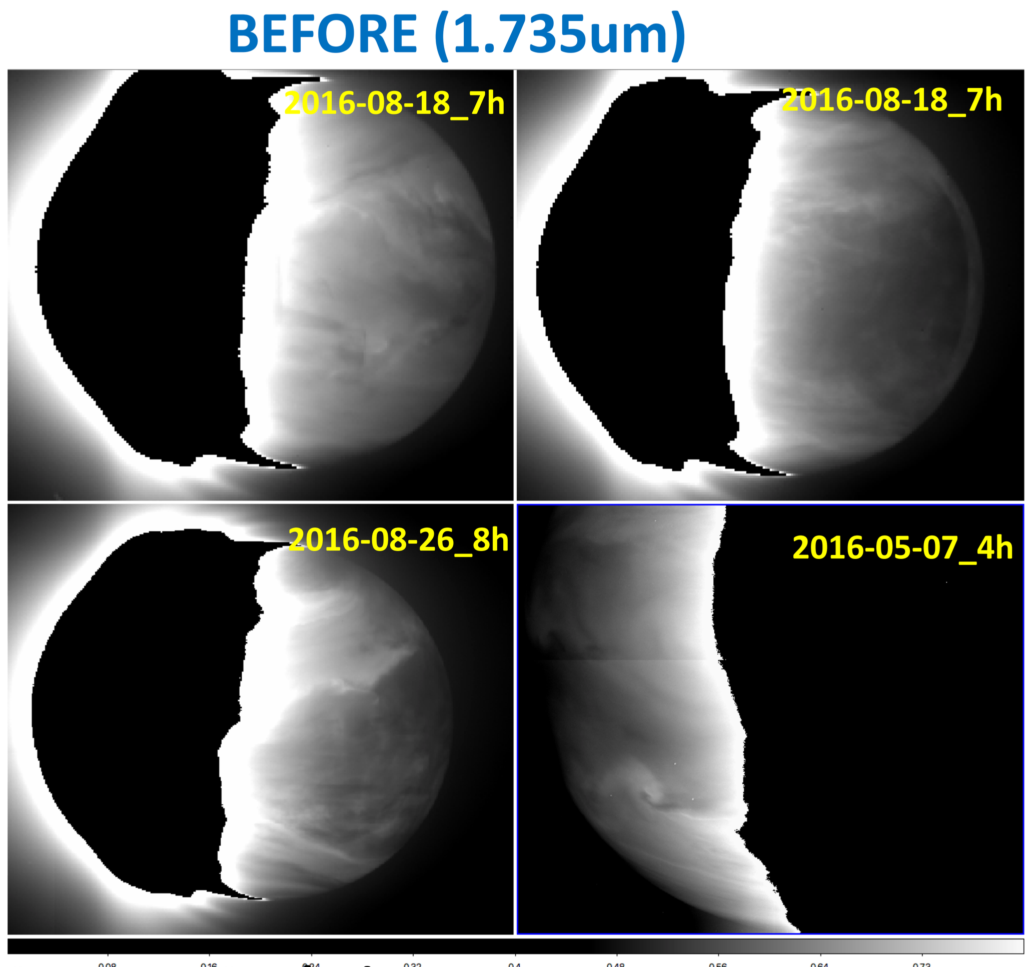
Brief De-convolution process schematics

Methods

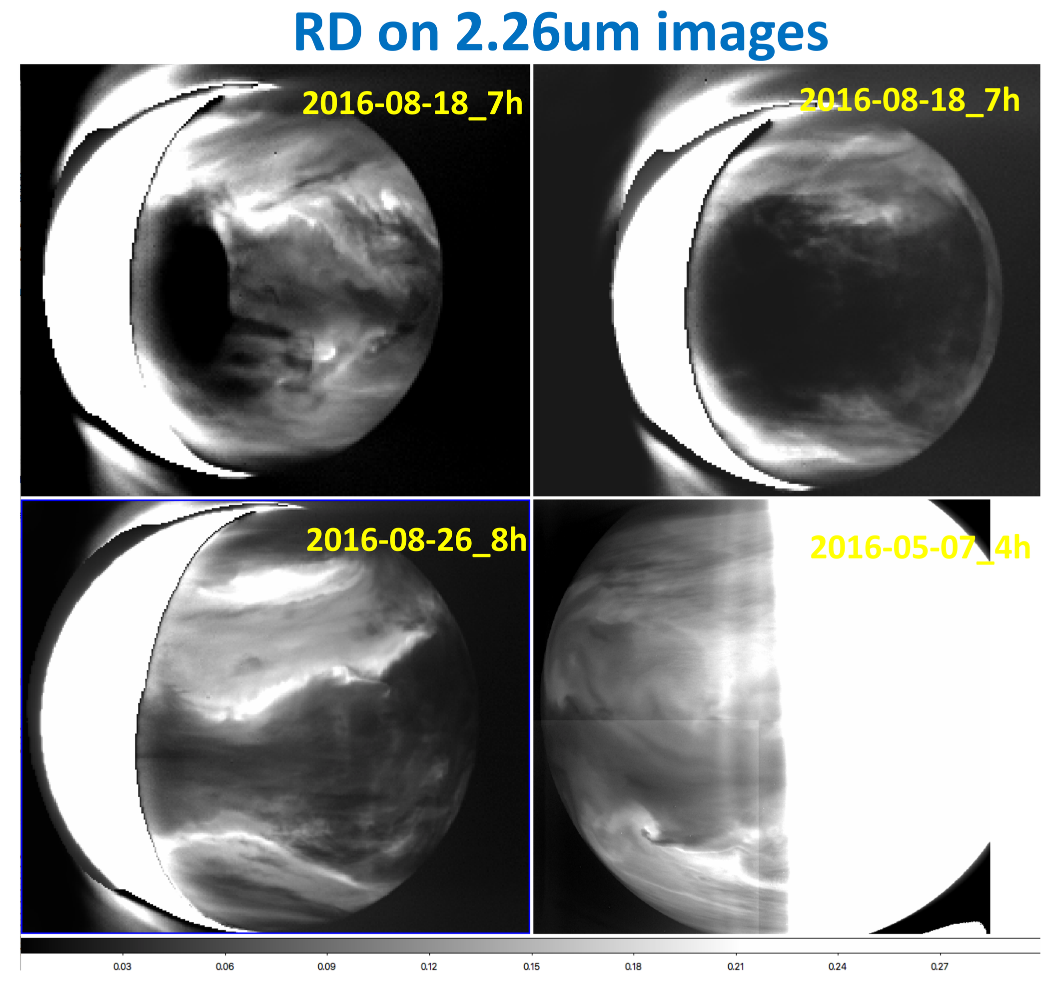
1. PSF modelling
2. Dayside modelling and Nightside conversion
3. (2) convolved by model-PSF
4. Saturation substituted by (3)
5. Deconvolution by model-PSF

Result

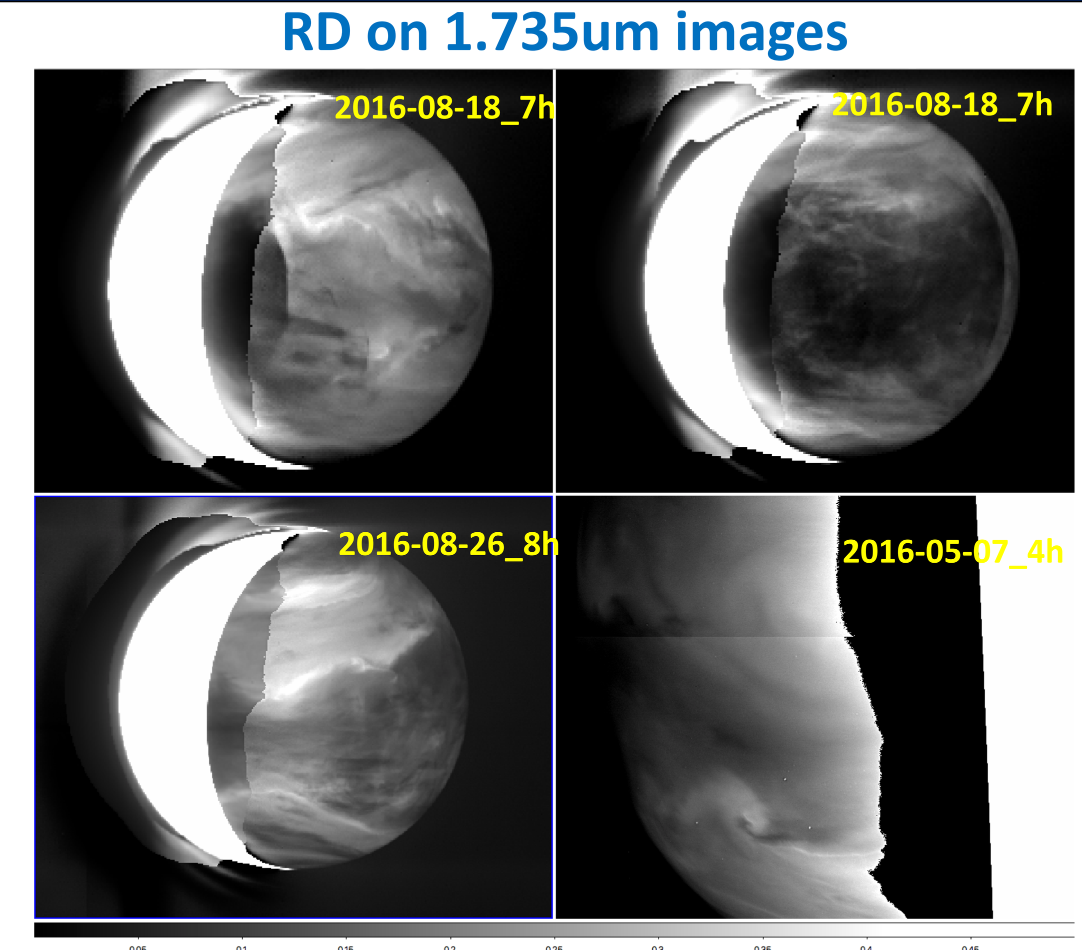
BEFORE (1.735um)



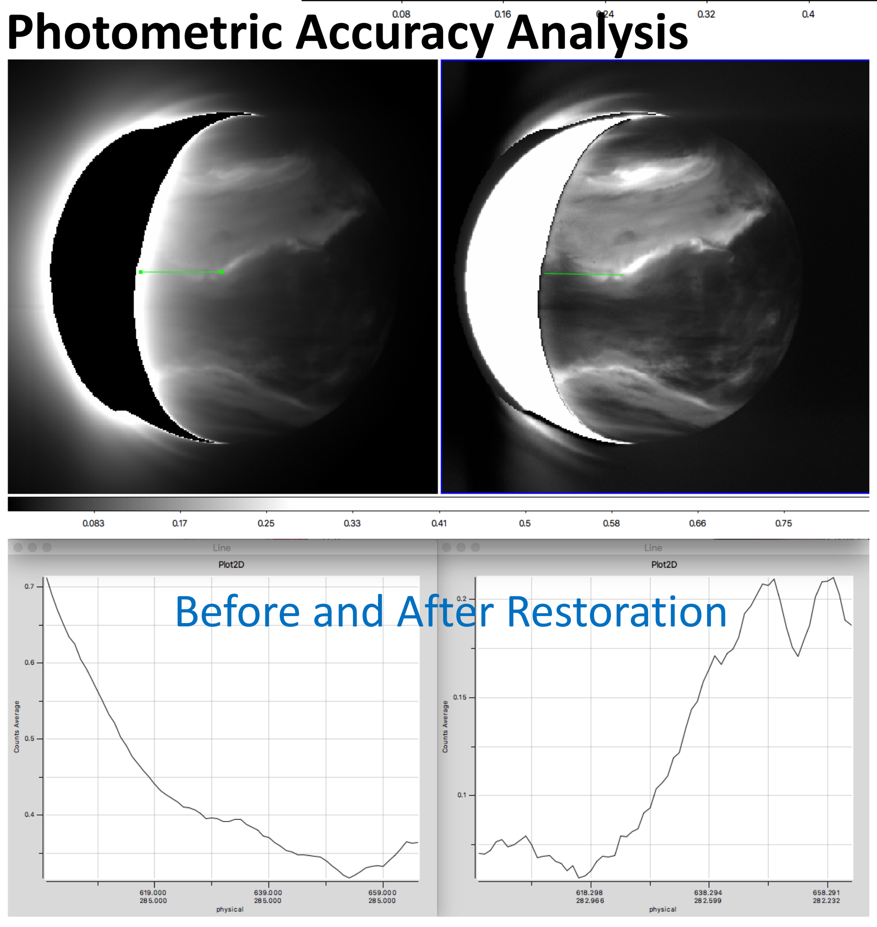
RD on 2.26um images



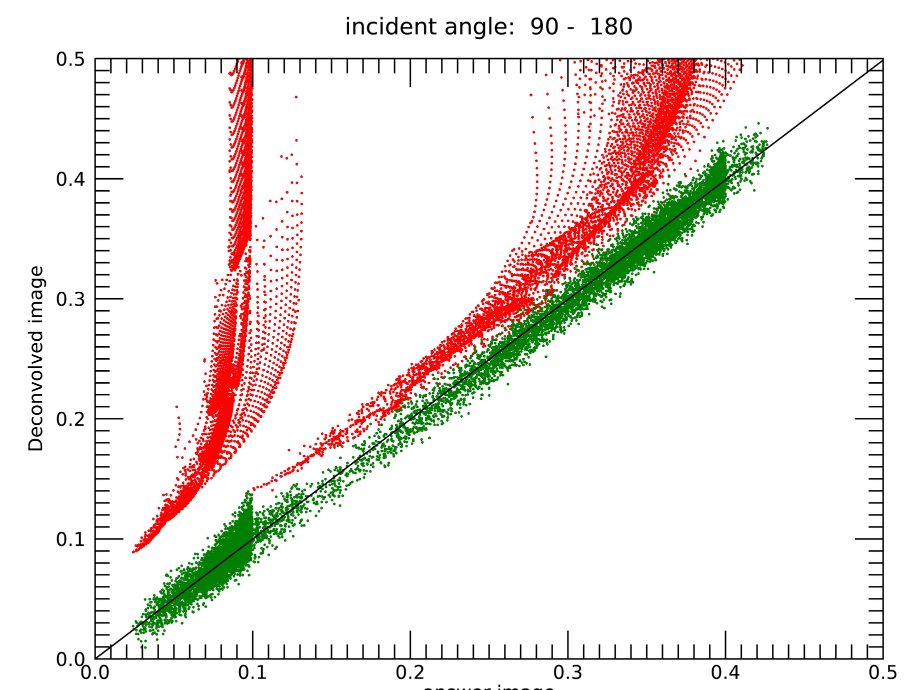
RD on 1.735um images



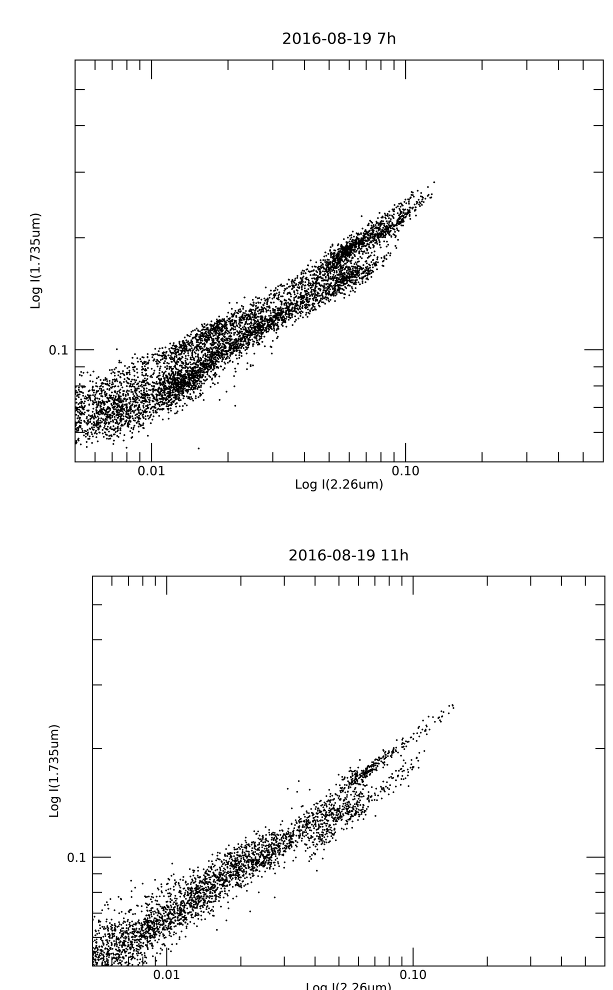
Photometric Accuracy Analysis



Before and After Restoration



Synthetic simulation on Pixel Restoration by RD. (Red) Before RD. (Green) After RD



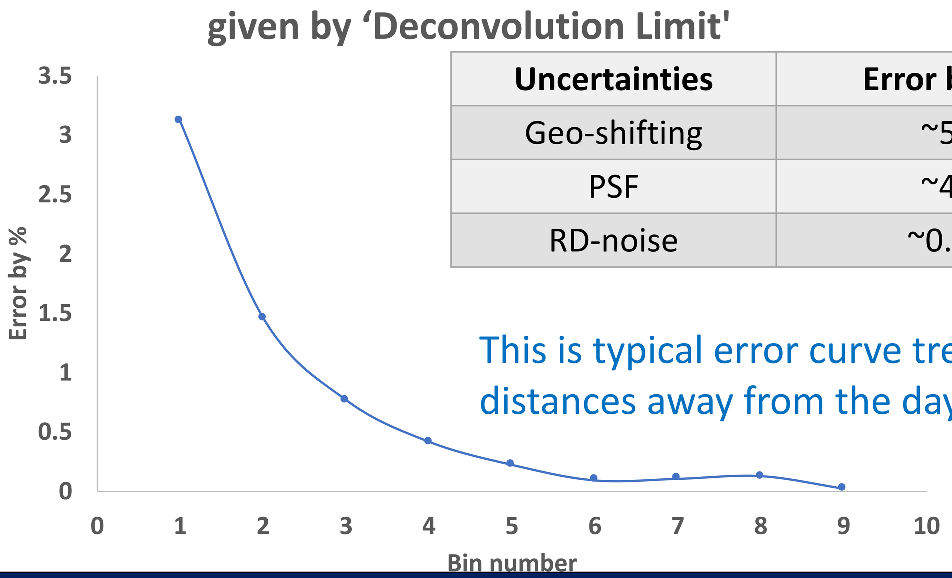
Hint on cloud particle sizes

Difference in cloud opacity of different particle sizes gives 'branches' in 1.735um-2.26um correlation plots.

Branches in the 1.735um-2.26um indicates different particle size modes: mode 2(1um), mode 2' (1.4um), and mode 3 (3.65um). [Carlson et al. 1993, Wilson et al. 2008]

Uncertainty Range

Error by % at distances away from dayside given by 'Deconvolution Limit'



Uncertainties	Error by %
Geo-shifting	~5
PSF	~4
RD-noise	~0.5

This is typical error curve trend for distances away from the dayside

Equations

Equation 1 – Lucy-Richardson Deconvolution

$$image_{n+1} = image_n \left(\frac{original\ data}{image_n * PSF}\right) \text{[reflect(PSF)]}$$

Equation 2 – Moffat function for PSF modelling

$$a_{total} = g_1 a_1(r) + g_2 a_x(X) \times a_y(Y)$$

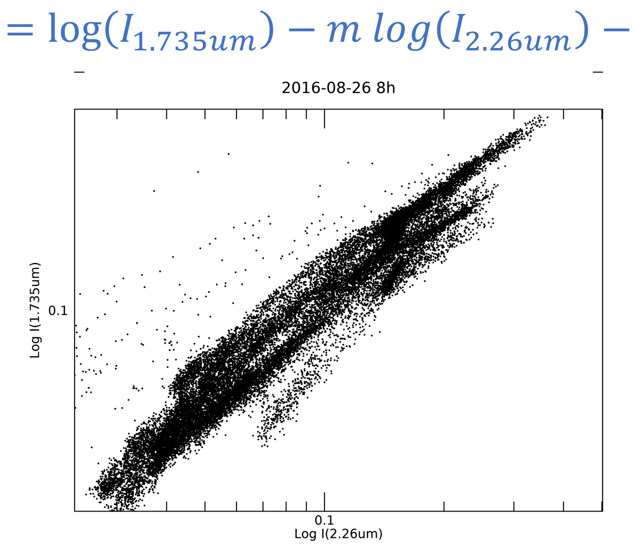
Where

$$r^2 = X^2 + Y^2 \qquad a_r(r) = \frac{1}{\pi}\frac{\Gamma_1}{2}\frac{1}{[r^2 + (\Gamma_1/2)^2]^{e_1}}$$

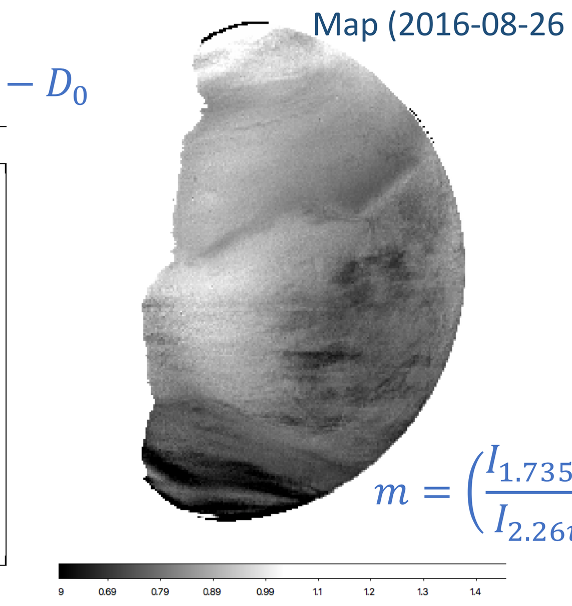
$$X = x - x_0 \qquad a_r(X) = \frac{1}{\pi}\frac{\Gamma_1}{2}\frac{1}{[X^2 + (\Gamma_2/2)^2]^{e_2}}$$

$$Y = y - y_0 \qquad a_r(Y) = \frac{1}{\pi}\frac{\Gamma_2}{2}\frac{1}{[Y^2 + (\Gamma_2/2)^2]^{(e_2 c)}}$$

$$D = \log(I_{1.735um}) - m\,\log(I_{2.26um}) - D_0$$



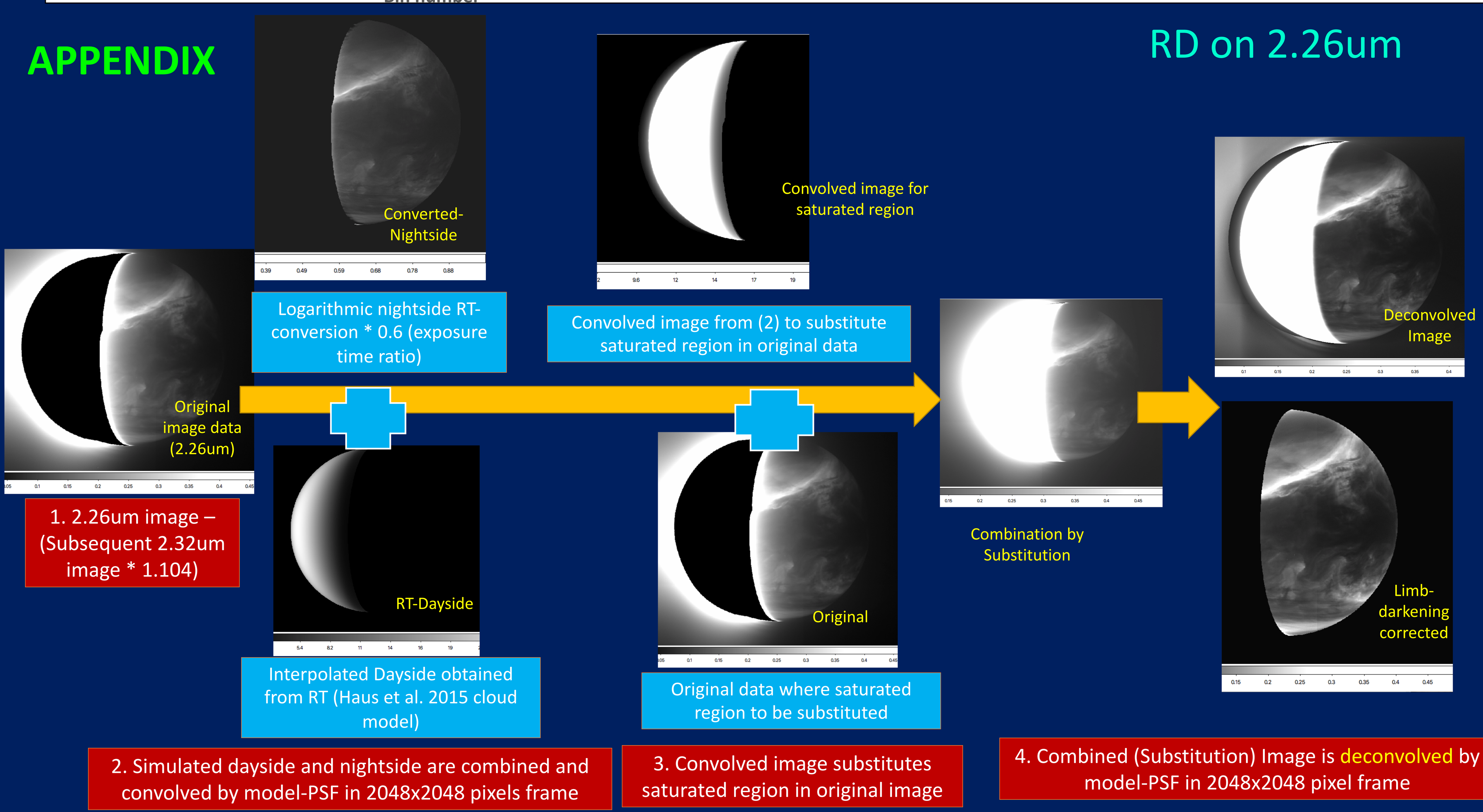
Example Size Parameter Map (2016-08-26 8h)



$$m = \left(\frac{I_{1.735um}}{I_{2.26um}}\right)^{0.53}$$

APPENDIX

RD on 2.26um



RD on 1.735um